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with the Authors Compts.

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XXXVII.—On a Remarkable Volcanic Agglomerate near Dundalk. By Joseph Nolan, M. R. I. A., of the Geological Survey of Ireland.

[Read, April 11, 1877.]

The Geological Survey of this district being completed, the following Paper has been drawn up as the result of observations made during the progress of that work, and is published with the consent of the Director-General:—

The theory of the close connexion between the plutonic or hypogene and the volcanic rocks, though for a long time much contested, has now I believe received all but universal acceptance. These two classes can no longer be regarded as essentially distinct, but respectively the lowest or deep-seated and the highest or subäerial members of one continuous system, of which the former, through the effects of denudation, is better exposed for observation in the older rock systems, while the latter, though not without its ancient representatives, is more clearly exemplified in the lavas and other volcanic products of recent times. Occasionally opportunities for a study of the connecting links between these extremes are afforded in the half-ruined volcanic systems of an intermediate period, and in Professor Judd's very excellent Paper on the ancient volcanos of the western islands of Scotland we have an admirable illustration of this kind.* I shall endeavour to demonstrate to you this evening that we have, nearer home, a somewhat similar example, though on a far less magnificent scale, yet possessing a special interest of its own, from the peculiar character of the volcanic products and the extraordinary modification of the phenomena to which they are due. The district I refer to is the hill country north of Dundalk, of which the rugged mass of Slieve Gullion occupies the central and principal portion. This mountain is entirely composed of massive igneous rocks, to which reference will be made in a subsequent part of this essay; the low-lying districts around the base are occupied by a coarse disintegrating granite of Silurian age; while at some distance from and forming a semicircular rampart round the mountain is a chain of low hills, composed of quartziferous felstone porphyry, and on the tops and exterior slopes of these hills is found the remarkable agglomerate which forms the more immediate subject of the present Paper.

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* "Quart. Journ. Geol. Soc.," vol. xxx., p. 119, part 3.

Commencing our examination of this district at the south-east, we find in the immediate neighbourhood of the historic pass and castle of Moiry† the low hill of Slievenabolea, composed of Silurian slates, vertical or inclined at high angles, and capped by the agglomerate. The upper portion of this singular rock has here all the appearance of a slate breccia, being mostly made up of pieces of slate similar to that which forms the mass of the hill in a base or matrix of finely comminuted slate fragments. As deeper portions are examined, the almost exclusive slate-breccia character disappears, and fragments of granite, diorite and other local rocks are found, particularly of the quartziferous felstone porphyry of the district, which latter increases in quantity in the lower portions till it ultimately forms the base. Thus, the fragmentary rock passes downward by insensible gradation into a vertical pipe of felstone, which evidently fills up the throat or chimney of a volcanic vent. (See Plate, Section No. 1.)

Between Slievenabolea and the hill of Carrickbroad, which rises to the west, several patches of this agglomerate are found on the slate rocks, and a great mass of it occurs on the south-eastern slope of the latter hill, and also on the summit, where it forms the two remarkable prominences called *Daaikilmore*. Here, as at Slievenabolea, the intimate relations between the agglomerate and the underlying porphyry are well shown in vertical sections; the former, however, differs from that at Slievenabolea in containing a larger proportion of granite than of slate fragments. Moreover, it does not seem to mark a volcanic vent, as the entire hill is formed of the porphyry, from which it would appear that these singular rocky hummocks, together with similar patches occurring, as before remarked, near the base of the hill and on the slate rocks, are but small remnants of an immense mass of ejecta, which completely covered up the porphyry, and extended to some distance over the adjacent rocks.

At three-quarters of a mile west of the summit of Carrickbroad, on the south-eastern flanks of the neighbouring hill of Tievecrom, there is a considerable area occupied by this agglomerate, which graduates so insensibly into the porphyry of the hill, both in sections and at the margin, that it is impossible to find any line of demarcation, and an arbitrary boundary had to be drawn on the map. Portions of it also occur near the summit of Tievecrom and other localities in the neighbourhood, but it occupies by far the largest area at Slievebrack, about a mile and a-half north-west of the village of Forkill.

This hill of Slievebrack, like the others just mentioned, is also composed of quartziferous felstone porphyry, and the agglomerate fills up a longitudinal hollow on its south-western flanks Its most extraordinary character here is, that it consists almost altogether of granite pieces of all sizes, from great blocks to the smallest fragments, in a base of fine granite dust or powder. From the peculiar position it occupies, and its great thickness, the base being in no place visible, it is most probable that this was the chief site or focus of the aëriform explosions which accompanied the intrusion of the porphyry, and to which this extraordinary mass of disrupted rock is undoubtedly due. (See Plate, Section No. 2.)

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† Erected by Lord Mountjoy in 1600. The pass of Moiry or Moyra was the scene of frequent conflicts between the Ulster Irish and the soldiers of the Pale.—See D'Alton's "History of Dundalk."

The exclusively local origin of the mass will also be evident from the change in its composition; granite fragments prevailing here, where that rock is found *in situ* on both sides of the hill; a mixture of granite and slate at Carrickbroad, near the junction of these formations, and slate fragments almost altogether at Slievenabolea, in the Silurian country to the south-east.

From this description it will be seen that the rock in question differs very much from the usual character of volcanic agglomerates, which consist of scoriæ and lava fragments, &c., sometimes mixed with a small proportion of the rocks through which the eruption took place, in a base of fine ash or tufa; while here not only the contained blocks but the base or matrix is made up of fragments of the pre-existing crust. This could not have been the case in an eruption of the usual character, where the igneous mass comes sufficiently near the surface to be discharged in lava or scoriæ, but was probably due to intense aëriform explosions originating at a greater depth, and extending in a longitudinal direction under a rather large area, producing several cracks and fractures, the rocks between which, thus loosened, were again and again thrown up and reduced by attrition to dust and fragments, forming a vast accumulation or hill of disrupted materials, the immense weight of which, in connexion probably with other causes hereafter to be mentioned, producing a cessation of volcanic power, so that the intumescent igneous mass was not further extruded, but cooled and consolidated beneath. Of this extraordinary modification of volcanic phenomena we have, if not perfectly similar, at least some very analogous examples in recent times, for to some such cause must be attributed the formation of those peculiar crater lakes or *maare* in the Upper Eifel. These are situated on the tops of slate hills, and were undoubtedly produced by explosion, as is evident from the quantities of ejecta that surround them. These latter, however, differ considerably from the tuff or ash thrown out from volcanoes, as they consist chiefly of slate fragments, the *débris* of the strata through which the crater was drilled, mixed up with a small proportion of scoriæ. "The volcanic energy," says Mr. Scrope, "had been impeded by the mass of transition and secondary strata which it had to pierce, and perhaps by the fragile nature of the greywacke slate, which, shattered and pulverized by the first few aëriform explosions of every eruption, would be likely to accumulate in great volume above and within the vent, and stifle its further activity" ("Volcanoes," p. 384). The resemblance between phenomena of this kind and that at Slievenabolea just described is very suggestive; and if we could examine a section through one of these craters we would doubtless find the slate-breccia graduating downwards into a subterranean lava, just as the similar fragmentary formation at Slievenabolea passes into felstone porphyry.

The igneous rock associated with the agglomerate has been already described as a quartziferous felstone porphyry. Its base varies from compact to finely crystalline, with orthoclase porphyritically developed, and usually some quartz, which latter mineral generally occurs as double-pyramidal crystals, and often in such quantity as to give the rock a pisolitic appearance.* Petrologically the rock might be called quartz-porphyry; but as that term is usually understood as synonymous with elvanite, which should only be applied to certain hypogene rocks of a granitoid character, I prefer not to employ it in describing a rock associated with volcanic ejecta. It may be regarded as the analogue among the older igneous rocks to the quartz-trachytes or liparites of the present day, to which, indeed, in some parts it bears a close resemblance, particularly like that of Ponza, which appears not to have been ejected at the surface, but to have consolidated beneath an accumulation of agglomerates and other ejected matters. As this mass of quartziferous felstone porphyry is traced to the north, it assumes a granitoid appearance, and mica and hornblende are developed, while the agglomerate thins out and disappears. Still further north this ridge of rock entirely loses its distinctive character, and merges into the great mass of quartzo-felspathic and hornblendic rocks that make up a large portion of Slieve Gullion, and the principal part of the hilly promontory between the bays of Dundalk and Carlingford.† (See Sketch Map, Plate xiv.) This granitoid rock has been already described by many observers, among whom we may mention Mr. Hamilton, Sir Richard Griffith, and Rev. Dr. Haughton, whose valuable Papers on the chemical composition of this and the associated rocks are well known. It may be generally described as a crystalline-granular aggregate of quartz and orthoclase felspar, with a greater or less admixture of mica or hornblende, particularly of the latter mineral, which is sometimes present in considerable quantity. In this part of the mass the quartz, though it does not crystallize out in the remarkable double-pyramidal form so characteristic of that portion in connexion with the agglomerate, still for the most part occurs as distinct crystals or blebs, while in other places it forms the base or skeleton of the rock; proving that some portions consolidated under much the same conditions as granite, the silica remaining in solution while the other constituents crystallized out.

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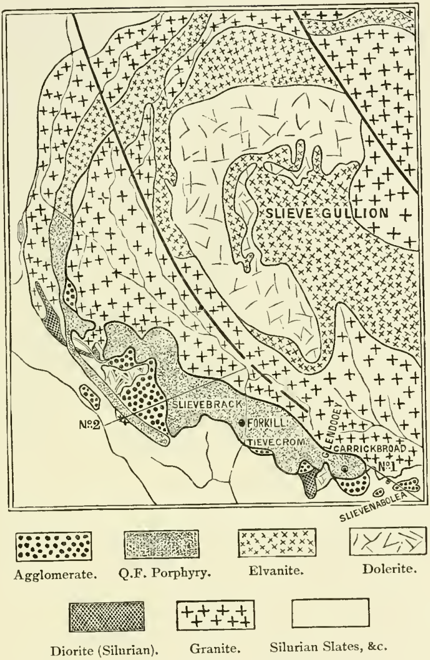
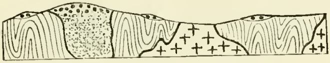
* This remarkable form of quartz was also observed in the Tardree Rhyolite. It is interesting to find so close a resemblance in the form of crystallization of the silica in the Forkill porphyry and a well-known recent volcanic rock.

† For this observation I am indebted to my colleague, Mr. F. W. Egan, B. A., who surveyed the northern portion of the district.

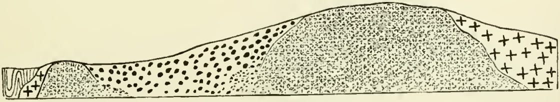


Sketch Map of the Slieve Gullion and Forkill District.

[Scale—half-an-inch to 1 mile.]



Section No. 1.—Across Slievenabolea.



Section No. 2.—Across Slievebrack.

[Scale—3 inches to 1 mile.]

TO ILLUSTRATE MR. NOLAN'S PAPER ON THE VOLCANIC AGGLOMERATE.

Associated with these acidic hypogene rocks are others of a basic character. Some of these are hornblendic, consisting of hornblende and plagioclase felspar; but by far the greater portions are pyroxenic, and exhibit every variety of texture and composition, from coarse hypersthene rocks and micaceous dolerites in what seem to have been the deeper portions, to finer grained dolerites or anamesites, and still finer augitic rocks, which from their close and compact texture we might almost regard as basalt.* These basic hypogene rocks seem also to have their volcanic representatives accompanied with agglomerates in various detached bosses and tracts among the hills previously described. One of the most remarkable of these is to be seen at Glendooey, where a mass of fine-grained basic rock rises abruptly from the hill side east of the glen. This is certainly an old volcanic vent; the upper portion of the rock is brecciated and agglomeritic, while the base is so closely associated with the tract of melaphyre to the south as to leave little doubt that it proceeded from it.† Another tract, but of larger extent, occurs some miles north of this, but its relations to the surrounding rocks could not be learned; however, still farther north there are other detached masses of basic rocks which graduate at the top into agglomerate. At one of these localities, a little north of Mullaghbane mountain, the associated agglomerate contains a huge mass of Silurian slate. Similar caught-up masses were observed in several places over these hills.

All these basic rocks appear to be of later age than the felstone porphyry, as they have been protruded through it; yet in the Slieve Gullion and Carlingford district the basic rocks seem to be the older, as they are frequently penetrated by dykes and veins from the associated acidic rocks. Possibly these latter have re-melted portions of the old basic rocks, and so given rise to the later pyroxenic eruptions.

Thus it will be seen that the phenomena observed in this district bear a remarkable similarity to that already referred to in the western islands of Scotland. In both localities we have a central mass or core of highly acidic rocks, graduating from those of a granitic type through porphyritic felstone or felsite to compact felstone, associated with others of a basic character, showing gradations from coarsely crystalline gabbros and hypersthenites to dolerite and basalt. The passage from hypogene rocks to those of a volcanic character forcibly reminds us of the late Professor Jukes's observation, that "if we could follow any actual lava stream to its source in the bowels of the earth, we should, in all probability, be able to mark in its course every gradation from cinder or pumice to actual granite" ("Student's Manual of Geology," p. 93). In the typical district of Mull, this almost prophetic announcement receives ample confirmation in the ultimate development of the granitic rocks into contemporaneous lava flows, with their accompanying scoriæ, ash, and lapilli; while in the Slieve Gullion and Forkill district, though the series is not so complete, we have nevertheless another remarkable illustration in the passage from hypogene rocks to others, which, though not actually volcanic, have by their protrusion produced mechanical accompaniments.

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* Rev. Dr. Haughton, whose detailed analyses of these rocks will be found in preceding numbers of our Society's "Journal," and elsewhere, shows that the felspar of this hypersthenite is not labradorite but anorthite, which is richer in lime, and is seldom found except in the lavas of Hecla, Vesuvius, and other volcanic districts.

† Professor Hull's microscopic observations prove that the rock consists of plagioclase felspar and epidote, the latter mineral occurring under such circumstances as to suggest the probability of its having replaced augite. See the "Geological Survey Memoir" to accompany sheet 70.

Having now described the igneous rocks associated with the agglomerate and the hypogene roots from which they were derived, it may be well to suggest another cause which may possibly have operated to check the volcanic activity at such a stage as to give rise to the formation of this peculiar mass of ejecta. In one of Professor Judd's admirable Papers recently published in the "Geological Magazine,"* he points out that in the ordinary case of eruptions from an habitual vent, it is probable that the underlying igneous matter occupies a vertical or nearly vertical dyke or throat, so that as pressure is diminished at the surface, and lava or scoriæ ejected, fresh accessions accrue from beneath, the elasticity of the steam, or water imprisoned in the interstices of the lava, causing it to rise, and produce thereby the ordinary phase of continued activity; while if the igneous mass be injected in nearly horizontal sheets or dykes, it will, when it comes sufficiently near the surface to overcome the pressure of the overlying rocks, disrupt the same over a large area, producing a sudden and wide-spread explosion, but of a very temporary character, as there are no deep portions vertically to furnish fresh supplies. Furthermore, according to the views held by Scrope, the coarse porphyritic lavas were, at the time of their intrusion, not in the condition of absolute molecular fusion, but rather granulated magmas with an interstitial fluid, the extreme tension of which is the sole motive power, and which, on being dissipated by explosion, leaves a solidified mass behind. Applying these considerations to the present case, we find that the Forkill porphyry occurs as a dyke-like protrusion from the great mass of granitoid rocks of the district, though in itself it is of no inconsiderable extent; so that the aëriform discharges were continued for some time, portions of the shattered crust being, as before remarked, thrown up again and again, and rounded and pulverized by attrition; but owing partly to the circumstances just mentioned, as well as to that before pointed out, viz., the immense weight and quantity of displaced materials, the volcanic energy was exhausted before the igneous matter could be developed into lava or scoriæ.

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* Vol. ii., No. viii., August 1875.

Of the age of these rocks we have little evidence, except that they are post-carboniferous, the limestone in contact being altered. They may be referred with much probability to that great period of volcanic activity which is believed to have taken place about the close of the Palæozoic epoch, as the physical changes that have since taken place are so vast. The western parts of the Slieve Gullion district seem to have been affected by a number of N. W. and S. E. faults, with downthrows to the west, of considerable extent, so that the great covering of Silurian granite, and other formations under which the hypogene rocks of the district must have been formed, were removed, and the latter now form the highest mountains, while the portions that, from clear evidence, originally formed the surface, are now found at a much lower elevation. This will be evident from a glance at the accompanying sketch map.

Professor Hull is of opinion that the neighbouring granite of Mourne is contemporaneous with these rocks, a supposition which seems extremely probable. In the Geological Survey Map of that district,* the granite is represented as passing in the marginal portions into elvanite, a circumstance which offers a fair presumption of its connexion with the same class of rocks in the district just described.